

NGST

Segmented Mirror Panel Technology

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Composite Primary Mirrors

Composite, segmented large mirrors have been developed for several purposes under ARPA and other Government funding, and this chart shows some of the results of that work. The performance goal for the High Altitude Large Optics (HALO) program was consistent with Near-IR sensor operation, with a 10-m aperture. The specific data describe equipment made and demonstrated in the early 1980s. These form the backdrop for later development for other programs, and for possible low-risk design approaches for NGST.

Low Temperature Mirrors Technology Issues

For composite primary mirror segments, another limit on design is due to differences in coefficient of thermal expansion (CTE) between the mirror components, and local CTE non-uniformity, particularly facesheet and substrate. A large difference, at fabrication or operational temperature, or during the cooldown cycle, can cause sufficient strain in the materials to impair the structural integrity of the units, or to degrade the response of the mirror face to actuation, if calibration is done for one temperature and operation is at another. These CTE issues impose a requirement to test mirror surface quality at operational temperature, and in the likely event that there is a large thermally-induced wavefront error, a surface error map must be made, then corrected at room temperature, before retest at the low temperature. Finally, since the deployment and phasing mechanisms must also operate at low temperature, the complete mirror should be tested at 30K, thus requiring a large thermal-vacuum chamber, instrumented for optical test, operating efficiently at that temperature.

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Composite Primary Mirrors

Technology Base- HALO Optics Technology (& other programs)- 1978 to 1986

Overview- Designed for 1/10 wave visible performance, for cold Vis/Near IR system

Demonstration based on 3-m aperture, to show feasibility of 10-m class segmented cryo systems

System operated at full performance at ~100K, critical items fully tested at 77K, some to 10K (for SIRTf)

Mirror Configuration- Lightweighted glass facesheet, supported by force actuators from Gr-epoxy substrate

Fabricated mirror size (2 made) 1 x 2.5 m, near-annular - area 2 m² each, 1x1-m first made as demo

Some details on construction - Total Mass/Area ~24 kg/m² (as measured in 1984 demo unit)

HALO Facesheet: Fused silica (CTE ~ 0 @ 60K), ~25 mm depth, square lightweighting pattern ~50 x 50 mm

Wall thickness - 2.5 mm (nominal), Face thickness - 2.5 mm (nominal) Variation ~±25 µm

Edge band (2 cm wide) not cored

Actual mass/area ~14 kg/m²

HALO Actuators: Small Kimco stepper motor, threaded shaft/nut, spring, graphite-epoxy tube assembly

Epoxy bonded to facesheet using Invar flexure/glass “button” assembly attached to gr-ep tube

Mechanical attachment to substrate used a self-centering Be-Cu radial flexure at each substrate face

45 (@ 0.23 kg) used for each large mirror, including wiring

Actual mass/area ~ 5 kg/m²

HALO Substrate: Graphite-epoxy, low expansion, CTE-match to fused silica lightweight semi-monocoque

Depth ~ 0.1 m; face-, backsheets provide inserts to mount actuator BeCu radial flexures and motors

Actual mass/area ~ 5 kg/m²

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insert development VG here
(to be scanned)

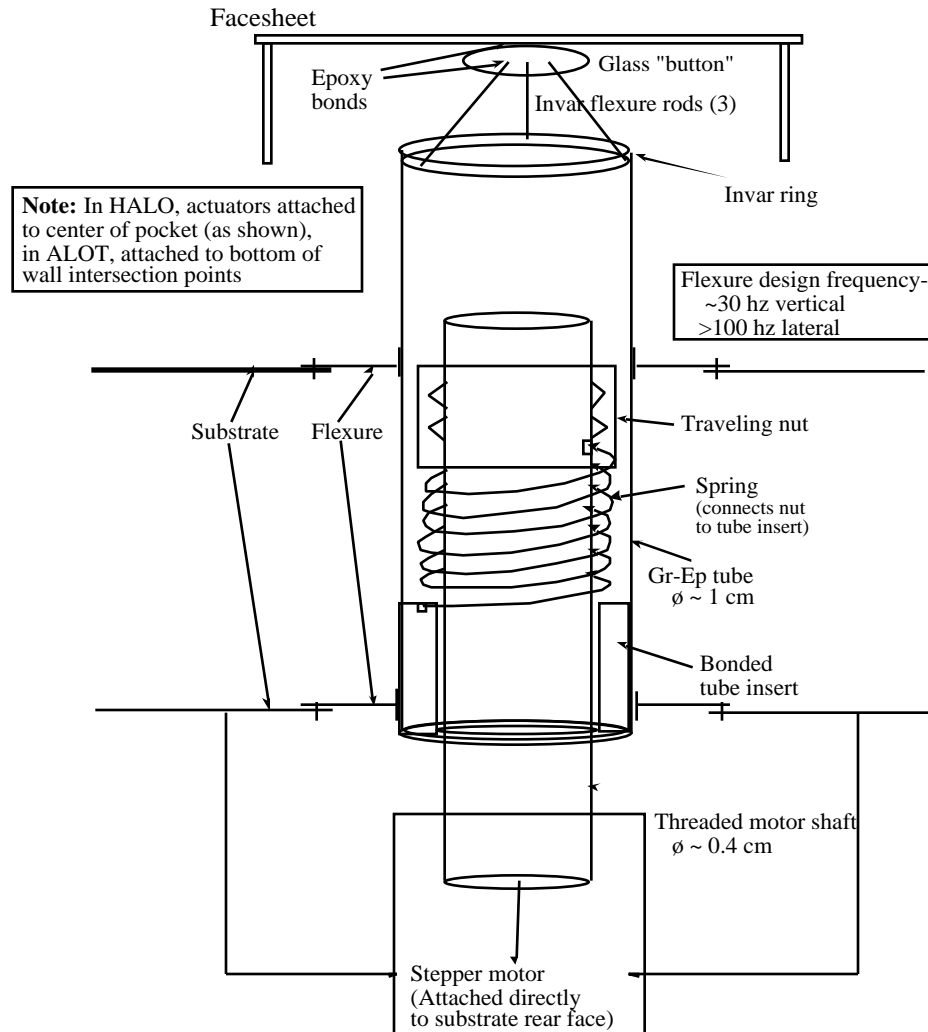
Composite Mirrors Technology Improvements

A late 1980s demonstration program, known as ALOT, extended the performance requirements to the visible, and required system operation in a highly dynamic, long-life environment. Therefore, the ALOT design emphasis was on low risk and high stiffness, rather than on low weight. Materials were improved, and all items were engineered and tested for flightworthiness, but the weight regime achieved was no better than HALO. Another demonstration, known as LOS, achieved 4-m dimension optical surfaces (center and edge panels of a 10-m class mirror), whereas ALOT provided 2.7-m in a center segment and a smaller outer panel. ALOT demonstrated full segmented mirror initialization, and both phasing and optical surface control over many months, using external reference sources.

Composite Mirror Schematic Configuration

The HALO-derived composite mirror configuration is schematically shown, based on the actuator as the focal point of the sketch. The lightweighted glass facesheet and semi-monocoque graphite-epoxy substrate are noted in passing, but their physical design has not changed much from HALO to the most recent designs for composite mirrors. The facesheets were of a “pocketed” construction, with both hard machining and chemical milling techniques used to achieve thin, precisely dimensioned walls and facesheets. The substrate was designed to be stiff and lightweight, and to accommodate the actuators which in turn support and control the operational shape of the facesheet. In the HALO program, the successful final telescope performance demonstration was done at 100K.

Composite Mirror Actuator Schematic Configuration



- Actuator and placement shown for HALO configuration
- Note indicates placement of actuator attachment for ALOT
- ALOT used PMN stack at glass attachment point to provide large stroke with high precision
- Weight of HALO device ~ 0.24 kg
- Weight of ALOT dual range unit, including redundancy ~ 0.45 kg
- Low temperature lubricant used for 77K-qualified HALO actuators was Molybdenum Disulfide Vespel

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Future Composite Mirrors

Based on the HALO, ALOT, LOS and other programs, the composite mirror design configuration is extrapolated here for application to NGST. This chart shows both glass and SiC facesheets applied to the design, with their different stiffnesses leading to a difference in spatial distribution of the actuator supports. While the weight predictions are not definitive, requiring further validation from structural model analyses, they should be representative of a low-risk design.

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Future Composite Mirrors

Projected weight reduction using Conservative technology improvement

Concepts configured for nominal constant performance of HALO mirrors - 1/10 wave vis/NIR

Component/Technology (Existing)	<u>HALO</u>	<u>NGST-A</u>	<u>NGST-B</u>
Facesheet:			
Material	Glass 25 mm deep, 50 mm sq cores 2.5 mm walls, faceplate	Glass 25 mm deep, 200 mm triang. cores 2.2 mm walls, faceplate	SiC (closed back) 15 mm deep 200 mm triang. cores 0.75 mm walls, 2 mm faceplates
Mass/Area (kg/sq m)	~14	~11	~ 8
Actuators:			
Assume HALO units	~22/sq m	~22/sq m	increase spacing ~15/sq m
Mass/Area (kg/sq m)	~ 5	~ 5	~ 3.5
Substrate:			
Material	Gr-epoxy, 0.1 m deep Lightweight, 2 faces	Gr-Cyanate Current COI config	Gr-Cyanate Current COI config
Mass/Area (kg/sq m)	~ 5	~ 4.5	~ 4.5
Total Mass/Area (kg/sq m)	~ 24	~ 20.5	~ 16

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Improved Composite Mirrors

The following further potential improvements in weight for the composite mirror still use the glass and SiC facesheets, but the weight predictions are based on operationally achieving the limits of fabrication performance projected from the prior development programs. Routinely achieving these parameters for NGST, including the mass/area ratio of the mirrors, will require substantial technology work, especially in scaleup of processes.

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Improved Composite Mirrors

Further Potential Weight Reductions

Overview: Apply only improvements producing significant weight reductions

Component/Technology (Existing)	<u>HALO</u>	<u>NGST-A</u>	<u>NGST-B</u>
Facesheet:			
Material	Glass	Glass	SiC (open back)
	N/A	2.0 mm walls, faceplate	20 mm deep, 1 mm walls, 2 mm faceplate
Mass/Area (kg/sq m)	0	- 1	- 2
Actuators:			
Replace by springs (30 hz vert, >100 hz lateral)	~22/sq m	~22/sq m	~15/sq m
Mass/Area (kg/sq m)	N/A	- 2.5	- 2
Substrate:			
Material	Gr-epoxy, 0.1 m deep no change	Gr-Cyanate Current COI config	Gr-Cyanate Current COI config
Mass/Area (kg/sq m)	0	0	0
Total Mass/Area (kg/sq m) ~	24	~ 17	~ 12

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Primary Mirror Segment Surfacing

Results required:

- Aspheric surface, several hundred λ from nearest sphere
- 0.03 μm rms or better surface error
- precisely matched f/1.25 figure (focal length) on segments
- 8 - 12 \AA surface roughness or better, no residual print-thru
- finished to very edge of lightweight facesheet surface
- cryo temperature operation

Mirror surface material- Fused Silica, SiC, Be (HIP) or other metal

Potentially available surfacing techniques

Conventional loose abrasive operation, post cutting

Ion figuring

CCOS- special lap control

Replication

- **CCOS has demonstrated all requirements, though not all at once; facilities available to 4 x 6 meters capacity**

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Primary Mirror Technology Base

Composite Mirrors - Glass/SiC Facesheet

<u>Attribute/Feature</u>	<u>Tech Demo Program (at Itek)</u>
Segment Fab (Non-circular shape)	HALO, LAMP, ALOT, LOS
4-m size (Facesheet, substrate)	LOS, ALOT
Surface quality	ALOT, LOS, MATS, 8105
f/1.5 or faster	ALOT, LAMP, LOS
Full surface figured (<3mm to edge)	ALOT, 8105
Ultra L/W facesheet	HALO, LPMA, ALOT, ULM,
Matched figure (radius)	LAMP, ALOT, 8105
Edge phasing (absolute)	LAMP, ALOT
Large SiC fabrication (1.1 x 0.9 m)	SiC Demo (AOMP)
Surface roughness (10 - 15Å)	ALOT, 8105, LPMA, SiC
Cryocycle of mirror assembly	HALO (105K), SiC (135K), Teal Ruby

TECHNOLOGY PROGRAM RECOMMENDATIONS

Area of OTA Need	Requirement	Time Frame GFY
1. Mirror Facesheet Material	Good figure at f/1.25, low mass	1997-8
2. Low Temperature Actuators Phasing, Figure	Operate for 10 yrs at low power, low weight	1997-9
3. Composite Mirror Assemblage	Achieve & hold phasing, figure	
4. Deformable Pupil Mirror	Operate at useful bandwidth to 0.01	1997-9
5. System Control Architecture (incl pointing, WF control)	Control phasing, pointing, wavefront error under all disturbances	1997-2001
6. Deployment Mechanisms	Survive launch, deploy within control capture range	1997-2000
7. System Performance and Cost Modelling	Support tech choice/development and control system cost	1997-2003